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ESTABLISHMENT OF THE SQUASH BUG PARASITOID, *TRICHOPODA PENNIPES* FABR. (DIPTERA: TACHNIDAE), IN NORTHERN CALIFORNIA

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Abstract.—The squash bug, *Anasa tristis* (De Geer) (Hemiptera: Coreidae), is an important pest of squash and pumpkin plants in California. Its pest status is partially due to a lack of specific nymphal or adult natural enemies in California. A nymphal-adult parasitic fly, *Trichopoda pennipes* Fabr. (Diptera: Tachnidae), commonly associated with squash bugs in eastern United States, was imported and released beginning in 1992 at several locations in Yolo, Solano, and Sacramento counties in northern California. This fly has successfully overwintered at four locations and has been recovered at two locations three years after initial releases.

Key Words.—Insecta, *Trichopoda pennipes,* biological control, squash bug, *Anasa tristis*

The squash bug, *Anasa tristis* (De Geer) (Hemiptera: Coreidae), is distributed from South America north to Canada, where it is one of the most important pests of cucurbits (e.g., squash, melons, cucumbers) (Beard 1940, Johannsen 1957, Nechols 1987). It is a frequent and particularly serious problem in California for producers and home growers of organically grown squash (personal observation, Flint 1990). Cultivars derived from *Pepo maxima* L. such as kabocha, red kuri, and hubbard cannot be grown in some areas without pesticides. The squash bug attacks all stages of the plant with the seedling stage being most susceptible to damage (Beard 1940). It reportedly injects a toxin during feeding and may transmit plant diseases (Eichmann 1945). During 1993 pesticide usage was reported on 8300 acres of California squash and pumpkins, of which some portion was used for control of squash bug (State of California 1993).

Trichopoda pennipes Fabr. is a nymphal-adult parasitoid that attacks squash bug infesting cucurbits in northeastern United States. It is the most widely distributed member of *Trichopoda,* found throughout North America south to Argentina and from the West Indies to California (Beard 1940). In the United States it reportedly has three geographically isolated strains (Dietrich & van den Bosch 1957). Only the strain from northcentral and northeastern United States attacks the squash bug. In Connecticut, it has been reported parasitizing up to 84% of overwintering adults (Beard 1940). A second strain occurs in the southern United States where it attacks pentatomids (stink bugs), and a third exists in California where it attacks the bordered plant bug, *Euryopthalmus cinctus californicus* Van Duzee, a largid which is sometimes found in cucurbits (van Driesche 1970, Dietrich & van den Bosch 1957). Dietrich & van den Bosch (1957) tried unsuccessfully to cross flies from southern California with those from Connecticut. They also observed that flies from Connecticut did not attack the bordered plant bug. *Trichopoda pennipes* collected in southern California readily attacked the bordered plant bug but did not attack squash bugs. It is possible that the different

strains are sibling species, morphologically identical but incapable of interbreeding and biologically distinct.

The absence of squash bug natural enemies in the Pacific Northwest prompted the state of Washington to import *T. pennipes* from northeastern United States during 1943–1944 (Clausen 1978). Observations in 1951 found ca. 50% parasitism over a large area of the state in late summer and autumn. Dietrick & van den Bosch (1957) imported *T. pennipes* from Connecticut in the 1950s but failed to established permanent populations in southern California. The lack of squash plants the following spring near their release site depleted the local squash bug population, and thus hosts for the parasitoid (Dietrick personal communication).

The successful importation of *T. pennipes* in Washington and limited efforts at establishment during the 50s in California warranted a second effort at importing this fly into this state. Furthermore, our surveys have recovered only small numbers of the egg parasitoid *Ooencyrtus californicus* Girault (Hymenoptera: Scelionidae) in late season when densities of squash bug are at their highest levels. Specific natural enemies of the nymph or adult squash bug stage have never been observed in our surveys or by others (Dietrick & van den Bosch 1957). We report on the importation, rearing, release, initial distribution, and colonization of *T. pennipes* for control of squash bug.

Materials and Methods

Field collection and shipment of parasitoids.—From June through August, 1992 and 1993, parasitized bugs were collected by one of the authors (MPH) from plantings of cucurbits (primarily zucchini) from four organic farms in Schuyler, Cayuga, and Seneca Counties of New York, one to eight collections per farm per summer. Bugs were considered parasitized if found with one or more tachinid egg(s) attached to their body (Fig. 1). The bugs were placed in 3.8 liter paper cartons, ca. 40 bugs per carton, with screen tops and with fresh sections of cucumbers or squash every two days. Environmental conditions were ca. 21° C (room temperature) and natural day length. Parasitoids were sent to the California Department of Food & Agriculture's Biological Control Program facility in Sacramento as puparia or as larvae inside of adult bugs, using overnight express mail.

Rearing and release of parasitoids.—In 1992 and 1993, 335 and 151 adult flies, respectively, emerged and were either directly released into squash fields or, under laboratory conditions, used to parasitize locally collected bugs that were subsequently released. These bugs were held inside standard sleeved cages (DeBach 1964) in rooms set at 20 to 27° C (14L:10D) and fed zucchini squash. No evidence of pathogens or hyperparasitoids were observed among the imported flies and bugs. In 1992, parasitoids were released at three locations in northern California with high squash bug populations: an organic private home garden in Davis (Yolo Co.), and two organic farms, one near Guinda (Yolo Co.), and a second near Winters (Solano Co.). None of these growers used insecticides. A total of 243 adult flies and 947 parasitized adult bugs were released among these three locations. In late summer 1993, 2440 parasitized bugs were released at the Student Experimental Farm of the University of California (UC), Davis and another 260 at an organic farm in Sacramento County.

In 1994 and 1995 an outdoor insectary or nursery site was established at the UC Davis Student Experimental Farm to provide a large number of squash bugs

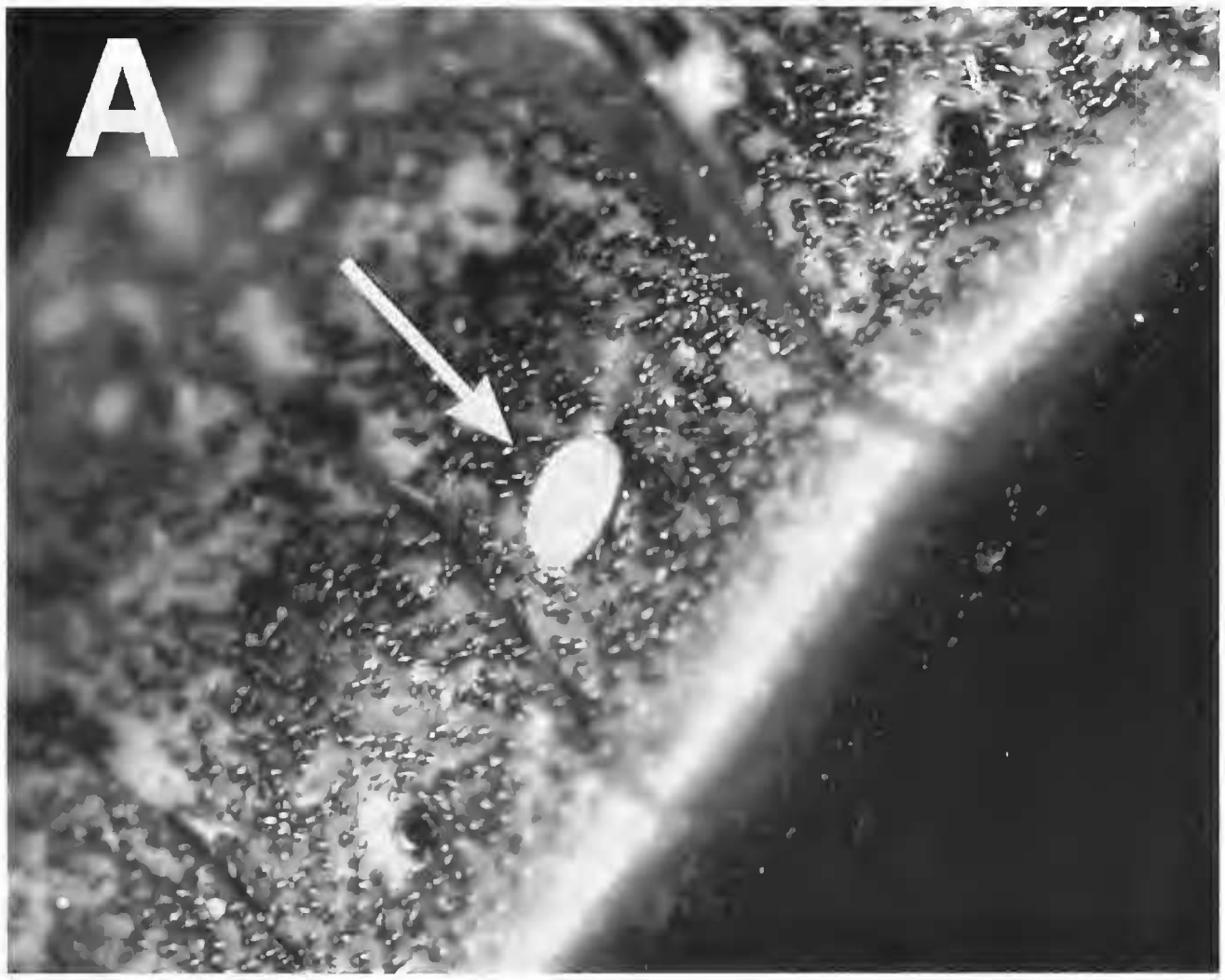

Figure 1. *T. pennipes* eggs on squash bug: (A) close-up view of single egg identified by arrow (photo by Jack Kelly Clark), and (B) cluster of eggs.

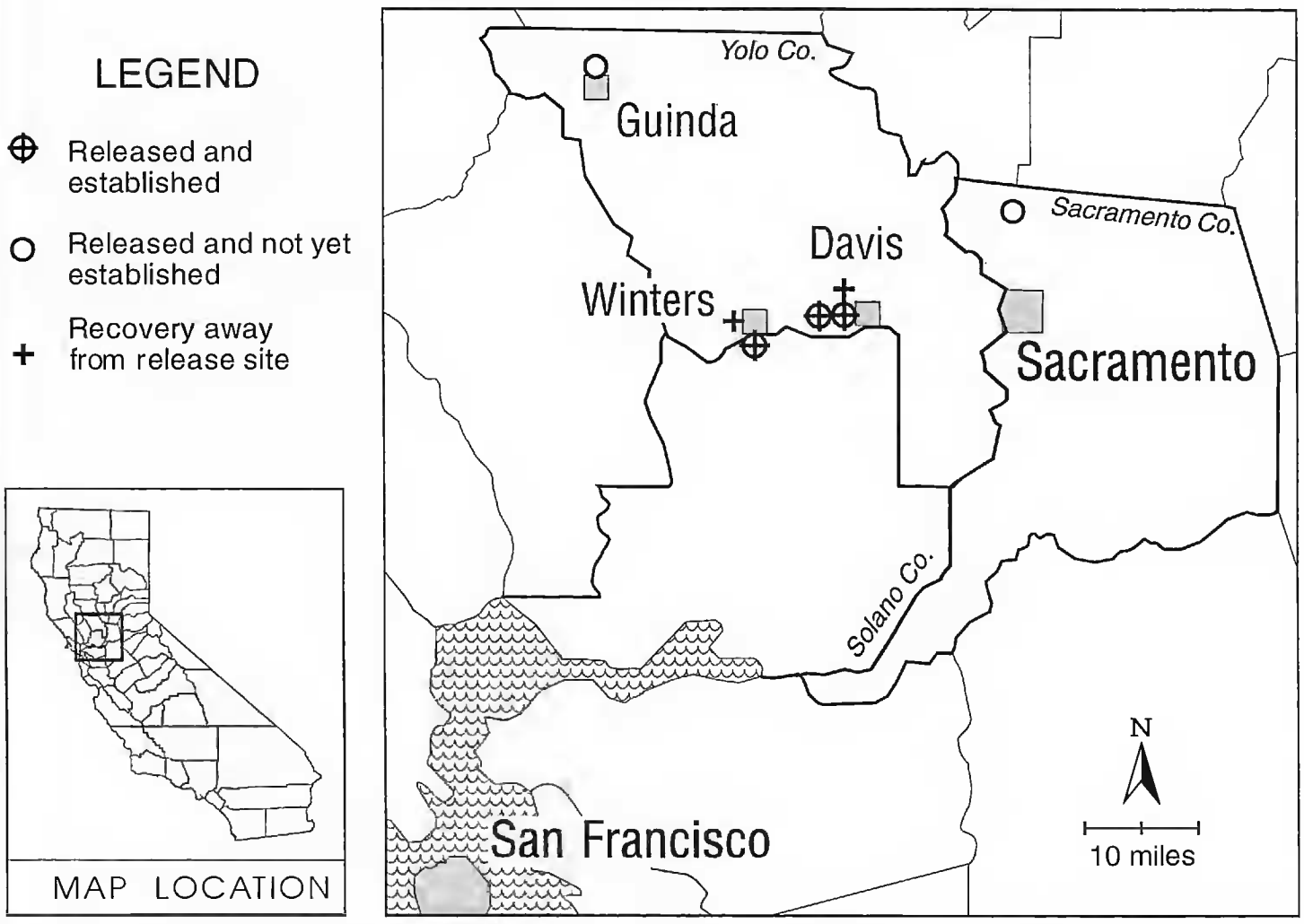

Figure 2. Release, recovery, and establishment locations for *T. pennipes*. Establishment implies *T. pennipes* has been recovered for at least one year since its release.

as hosts for overwintering flies from the 1993 releases. Crops planted at the Student Experimental Farm tolerate pest populations far above the economic threshold of commercial growers. A mixture of zucchini and kabocha squash were planted to a 0.8 ha site on three dates beginning in late spring. Twenty thousand squash bugs were collected from surrounding farms and released to augment the local population. Every 5th row in the field contained a strip of annual buckwheat to provide with-in field nectar sources for *T. pennipes*. Honey and sugar water have been shown to increase the longevity and fecundity of *T. pennipes* in the lab (Shahjahan 1968), and during 1994 many flies were observed feeding atop the buckwheat flower heads. In 1994 and 1995 ca. 2100 flies were transported from this site and released at new release sites, including a former site located in Guinda.

Recovery.—Years following releases, adult squash bugs were collected from squash plants located within several hundred meters of original release sites. Adult bugs were collected two to three times at each location during summer months. Ten to twenty adult *T. pennipes* per site per summer were reared from field collected bugs with fly eggs (Fig. 1) to confirm identity of the parasitoid.

Results and Discussion

In 1993, *T. pennipes* was recovered at all three 1992 release sites (Fig. 2). However, we were unable to recover parasitoids at the Guinda site in late summer. We recovered parasitized squash bugs from the UC Davis site in 1994, 1995, and 1996, representing a fourth site in which the parasitoids successfully overwin-

tered. In 1995 we observed squash bugs with tachinid eggs in Winters (Everything Under the Sun Farm), and the following spring we recovered the same at Terra Firma showing that the fly population persisted at these two sites through three winters, producing multiple generations. The same parasitoid in northeastern United States produces three generations during summer months while the squash bug produces one (Beard 1940). Populations of introduced natural enemies that have persisted for at least three generations or three years are most likely permanently established (DeBach 1964). *Trichopoda pennipes* dispersed long distances from release sites. In 1994, *T. pennipes* was found 8.0 km from the original release site in the Winters area (Terra Firma Farm) and in a residential garden 2.5 km distant from the UC Davis student farm insect nursery site.

The percentage of bugs with parasitoid eggs varied from 1.3 to 92.2 at release sites (Table 1) and no other species of Tachinidae were reared from these individuals. These values underestimate the full potential of this parasitoid because we were adding unparasitized bugs and/or removing parasitized ones while these data were being recorded. Furthermore, sufficient generations have not yet passed for this parasitoid to have become established over a large area.

Releases of *T. pennipes* have persisted for three years at two locations in northern California and the parasitoids have dispersed up to 8.0 km from original release sites. This is the first specific natural enemy successfully established against the squash bug in California. Observations in New York and Washington suggest that this parasitoid could become widely established and have a major impact on squash bug. Although squash bug can be considered a problem to some growers of cucurbits in New York, most of the bugs collected there for shipment to California were parasitized. The squash bug in Washington was rated as only a minor pest in the mid 1970s (Clausen 1978). Plantings of tachinid insectary plants in and around fields of squash could increase the impact of flies on squash bug (Pickett & Bugg in press). For organic farmers of specialty crops in California, the presence of *T. pennipes* may help reduce control costs and allow for the production of highly susceptible varieties of squash that command a higher profit margin. Similarly, home gardeners may not have to use pesticides or other control measures for the squash bug helping to reduce widespread urban use of chemical pesticides for this pest.

Acknowledgment

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Table 1. The number and percentage of adult squash bugs sampled with one or more parasitoid eggs attached to their bodies, 1993–1996.

Years following release	Site location (year recovered)	Total number of parasitoids released (as immatures or adults)[1]	Total number of adult bugs examined	Number with parasitoid eggs	Percentage of adults with parasitoid eggs
One	Davis—UCD Student Farm (1994)	2440	1300	205	15.8%
	Davis—private homeowner (1993)	192	100	20	20.0%
	Davis—Village Homes Community Garden (1994)	immigrated	141	130	92.2%
	Winters—Everything Under the Sun Farm (1993)	564	300	60	20.0%
	Winters—Terra Firma Farm (1994)	immigrated	906	350	38.6%
	Guinda—Full Belly Farm (1993)	432	1350	18	1.3%
	Guinda—Full Belly Farm (1996)	4434	68	14	20.5%
Two	Davis—UCD Student Farm (1996)	2000	683	516	75.5%
	Winters—Terra Firma Farm (1995)	resident	2622	1476	56.3%
Three	Winters—Everything Under the Sun (1995)	resident	30	15	50.0%
	Winters—Terra Firma Farm (1996)	resident	65	51	78.5%

[1] "immigrated" implies that recovered parasitoids had dispersed to a site, and "resident" implies that no additional parasitoids had been released the previous year(s).

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